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(71) Applicant *(for all designated States except US)*: HÖGANÄS AB [SE/SE]; S-263 83 Höganäs (SE).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: JACK, Alan, G. [GB/GB]; Milestone House, Allendale Road, Hexham, Northumberland NE46 2NB (GB).

(74) Agent: AWAPATENT AB; Box 5117, S-200 71 Malmö (SE).

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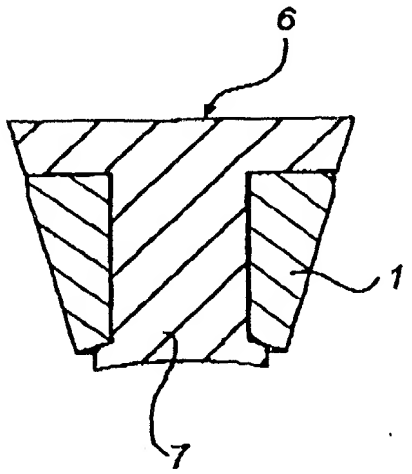
(54) Title: METHOD OF PRODUCING AN ARMATURE SEGMENT OF AN ELECTRICAL MACHINE




(57) Abstract: An armature segment (6) of an electrical machine includes a coil (1) and a core section (7). A method of producing such a segment comprises the steps of tightly winding the coil (1), providing a compaction die (2) having a cavity for shaping the tightly wound coil (1), introducing the tightly wound coil (1) into the compaction die (2) and compacting the coil (1) therein so as to reduce the volume occupied by the coil (1), providing a compression-moulding die (5) having a moulding cavity, positioning the compacted coil (1) in the moulding cavity of the compression die (5), filling the moulding cavity with insulated ferromagnetic particles, and compressing the insulated ferromagnetic particles in the moulding cavity so as to form the armature segment (6) as a single-piece unit including the core section (7) and the compacted coil (1).

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# METHOD OF PRODUCING AN ARMATURE SEGMENT OF AN ELECTRICAL MACHINE

## Technical Field

The present invention generally is related to electrical machines, especially motors, and more precisely to a method of producing an armature segment of an electrical machine, which armature segment includes a coil and a core section.

## Background of the invention and the prior art

Electrical machines work by the interaction of magnetic flux and current. At operating limits the magnetic flux is limited by saturation of the soft magnetic material and the current by the temperature resulting from ohmic heating. If more space is provided for conductors to reduce current densities and hence ohmic heating, the magnetic flux is also reduced and vice versa if more soft magnetic material is included the flux is increased but the conductor area is reduced and ohmic heating increased.

In most machines the conductors are contained in slots. It is necessary to semi-close the slots to obtain a smooth torque output and the result is that placing the windings in the slots is a difficult task which results in a poor ratio of conductor area to slot area. Ratios in the region of 50% are considered good. This poor ratio is bad for two reasons, firstly space is wasted which could be used for conductor or soft magnetic material and secondly the space in the slot will act as a thermal barrier increasing the temperature for a given ohmic loss.

By integrating the coils of an armature in the body thereof, it should be possible to increase the ratio of conductor area to slot area. In other applications, it is

known to integrate a coil into a body made of compressed metal powder, Thus, SE-A-9501500 discloses a magneto-strictive sensor having a housing made of metal powder and a sensing coil integrated therein.

Summary

An object of this invention is to provide an armature, preferably a stator, for an electrical machine which armature has a better ratio of conductor area to slot area than armatures in the prior art.

A method of producing an armature segment of an electrical machine, which armature segment includes a coil and a core section in accordance with the present invention is characterised by the features specified in the appended claim 1. Preferred embodiments of that method are defined in the dependent claims.

Thus, this invention is concerned with first producing tightly wound coils. Then each tightly wound coil is placed in a die where it is compacted for shaping the tightly wound coil so that the cross-sectional area of the tightly wound coil is reduced. Preferably, this means that the cross-sectional shape of each wire of the coil is deformed toward a hexagonal shape. Thereafter, the compacted coil is positioned in a die for compaction of insulated iron powder to form an integrated coil and core unit. The armature of the machine is then assembled from a number of these units.

The coils being produced away from the geometric difficulties of insertion into the slots can have a far higher ratio of copper to slot area; using machine winding 70% is easily achieved. By the further step of compressing the coils in a die 81% can be achieved which is getting close to the theoretical maximum (which is fixed by the need for insulation around the conductors).

The result of this high ratio of conductor to slot area is a major reduction in coil resistance and excellent thermal conduction properties. At the same time, these coils may easily be produced using simple

bobbin winding technique using fully automated techniques which are not expensive to implement.

The compaction of the insulated iron powder with the previously compacted coil produces a finished component, thereafter only requiring a heat treatment before assembly with the other components. Another benefit of the compaction is excellent thermal contact between the core and the coil allowing high currents densities to be used and higher output to be achieved from the same material.

Brief description of the drawings

FIG. 1 is a perspective view of a pre-compacted coil used in the method according to the present invention;

FIG. 2 is a cross-sectional view of a die used for pre-compaction of the coil before compression thereof with a ferromagnetic metal powder;

FIG. 3 is a cross-sectional view of a part of the coil of FIG. 1 resulting from the compacting using the die of FIG. 2;

FIG. 4 is a cross-sectional view of a compression die showing the compacted coil positioned therein;

FIG. 5 is a cross-sectional view, taken in a plane normal to the planes of Fig. 2 and 4, of a co-compressed coil and core unit forming an armature segment according to the invention.

Description of the preferred embodiment

A coil 1 illustrated in FIG. 1 is made of copper wire having a surface layer of an insulation material. The copper wire is wound helically in several turns forming the multi-layered winding or coil 1.

In order to increase the conductor to slot ratio, the wire turns of the coil 1 should be placed in contact with each other. This is achieved by compressing the coil 1 in a die 2 as shown in FIG. 2, such that any spring-back effect of the coil wire is minimised. By the compression made in the die 2, each turn of the coil 1 contacts every neighbour turn thereof and preferably has

a cross-sectional shape which is deformed from circular towards a hexagonal shape, as shown in FIG. 3, giving the best possible conductor to slot ratio. FIG. 3 illustrates a plurality of wires 3 and the insulation 4 thereof in cross-section.

The compressed coil 1 is then removed from the compaction die 2 and positioned in a compression-moulding die 5 shown in cross-section in FIG. 4. More precisely, the compacted coil 1 is positioned in the moulding cavity of the die 5 in contact with the inner surface thereof. Thereafter, insulated ferromagnetic particles are filled into the moulding cavity of the die 5 and are compressed so as to form an armature segment, shown in FIG. 5, as a single-piece unit 6 including a core section 7 and a compacted coil 1.

Then, the single-piece armature segment 6 having the cross-sectional form shown in FIG.5, is removed from the die 5 and is heat-treated.

Ultimately, a plurality of single-piece armature segments may be assembled into a complete armature.

It is obvious to the man skilled in the art that several modifications are possible without departing from the spirit of the present invention.

As an example, part of the compaction die 2 may also be used as part of the compression die 5.

CLAIMS

1. A method of producing an armature segment of an electrical machine, which armature segment (6) includes a coil (1) and a core section (7), said method comprising the steps of

tightly winding the coil (1);

providing a compaction die (2) having a cavity for shaping the tightly wound coil (1);

introducing the tightly wound coil (1) into the compaction die (2) and compacting the coil (1) therein so as to reduce the volume occupied by the coil (1);

providing a compression-moulding die (5) having a moulding cavity;

positioning the compacted coil (1) in the moulding cavity of the compression die (5);

filling the moulding cavity with insulated ferromagnetic particles; and

compressing the insulated ferromagnetic particles in the moulding cavity so as to form the armature segment (6) as a single piece unit including the core section (7) and the compacted coil (1).

2. A method as claimed in claim 1, wherein the tightly wound coil (1) introduced into the compaction die (2) is compacted so as to deform the cross-sectional area of individual wires (3) of the coil (1) towards a hexagonal shape.

3. A method as claimed in claim 1 or 2, wherein the compaction die (2) partly is used as the compressing-moulding die (5).

4. A method as claimed in any one of claims 1-3, wherein the coil (1) is positioned in the moulding cavity of the compressing-moulding die (5) so as to form a surface layer of the armature segment (6).

5. A method as claimed in claim 1, wherein the coil (1) is positioned in the moulding cavity of the

compression-moulding die (5) separated from the surfaces thereof.

6. A method as claimed in any one of claims 1-5, wherein the coil (1) is preformed on a bobbin.

7. A method as claimed in any one of claims 1-6, wherein the compressing is performed at an elevated temperature.

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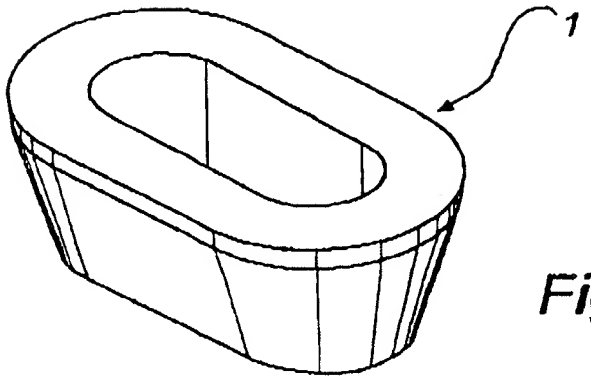


Fig. 1

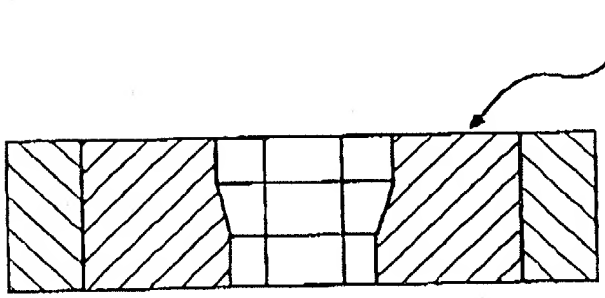


Fig. 2

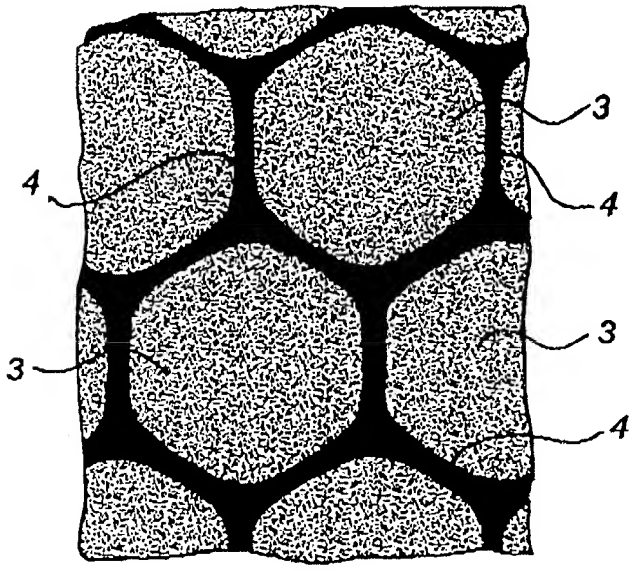


Fig. 3

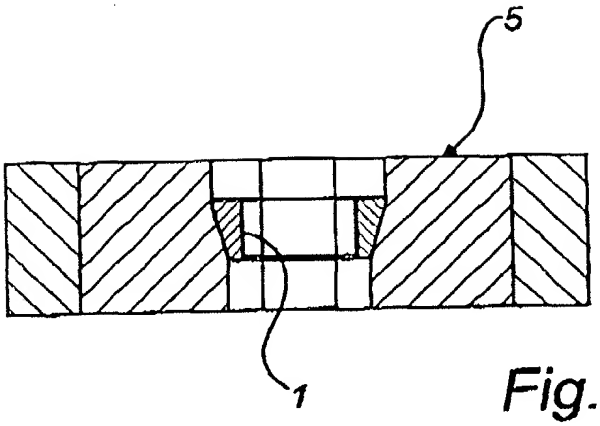


Fig. 4

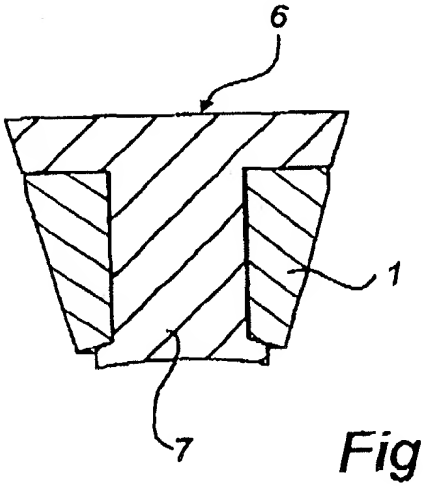


Fig. 5

# INTERNATIONAL SEARCH REPORT

International application No.
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## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B22F 3/00, B22F 5/00, H02K 15/00
According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B22F, H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, PAJ, EPODOC

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 4150927 A (ERICH A. STEINGROEVER), 24 April 1979 (24.04.79), column 1, line 61 - column 2, line 18, figure 1, abstract | 1-7 |
| A | US 5722032 A (DAVID EARL GAY), 24 February 1998 (24.02.98), figures 3,4, claim 1, abstract | 1-7 |
| A | US 5221503 A (ROBERT W. WARD ET AL), 22 June 1993 (22.06.93), column 1, line 42 - line 68, figures 4, 5, abstract | 1-7 |

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | GB 1457504 A (FRANCIS DEREK LOWEN), 1 December 1976 (01.12.76), claims 1-6 | 1-7 |

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Information on patent family members

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International application No.
PCT/SE 00/01521

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| | | | | EP | 0556914 | A | 25/08/93 |
| | | | | JP | 2024713 | C | 26/02/96 |
| | | | | JP | 6002002 | A | 11/01/94 |
| | | | | JP | 7015125 | B | 22/02/95 |
| GB | 1457504 | A | 01/12/76 | NONE | | | |